Energy Management Strategies Improved in Microgrid using a Non Linear Model Predictive Control

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***Abstract*—Energy management are essential for power sharing and voltage regulation purposes in standalone green microgrids. The classical technology employ maximum power point tracking algorithm and droop control methods. It can be control only two variables. The coordinated and multivariable energy management strategies is proposed that employs a wind turbine, battery system, a photovoltaic array of a standalone micro grid as controllable generators by adjusting the pitch angle and the switching duty cycles. Also improve voltage and current in each branch to be analysed. The proposed EMS is developed as an online novel NMPC strategy that continuously solves an optimal control problem (OCP) and finds the optimum values of the pitch angle and three switching duty cycles. It simultaneously controls four variables of micro grids are power coefficient of the wind turbine, angular velocity of the wind generator, operating voltage of the PV array and charging current of the battery bank. It is shown that, employing new available nonlinear optimization techniques and tools, the computational time to solve the resulting NMPC strategy is in permissible range. The on and off time data is obtained using track point. To analysed the past and present values of output, so that to predict future response of output as need in load demand.**

Keywords--NMPC, PVarray, ocp, energy management strategy, maximum power point tracking.

I INTRODUCTION

Energy can be naturally replenished. Technology should improve energy efficiency. The long term availability sustainable energy is one which is able to meet the growing demand of today's people without comprising the demand of people that would require it in future. Moreover, some serious environmental problems related to global warming and climate change have made people aware of brutal consequences that they may have to face if a switch to green and clean energy. Renewable energy is generally energy which are naturally replenished on a human timescale such as sunlight, wind, tidal, waves and geothermal heat. According to the many renewable energy experts, a small "hybrid" electric system that combine wind electric and solar electric technologies offer several advantages over either single system. Wind speeds are low in the summer when the sun shines brightest and longest. Dynamically, the master converter retains its original design characteristics; all the slave converters are forced to depart significantly from their original design characteristics into current controlled current source [1]. The wind is strong in the winter when less sunlight is available. Because the operating time for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when we need it.

The contemporary wind turbines are classified with respect to both their control features and drive train types, and their strengths and weaknesses are described [2]. The specification of a power electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total system [3][4]. power control strategy contains a virtual inductor at the interfacing inverter output and an accurate power control and sharing algorithm with consideration of both impedance voltages drop effect and DG local load effect [6].

Small autonomous power systems are extremely difficult to design and operate reliable [9] and variable-speed wind-generator maximum power point tracking (MPPT) based on adaptative neuro-fuzzy inference system[10]. Many hybrid systems are standalone systems, which operate off grid not connected to an electricity distribution system. For the time when neither the wind nor the solar system are producing, most hybrid systems provide power through batteries and or an engine generator powered by conventional fuels, such as diesel. If batteries run low, the engine generator can provide power and recharge the batteries. The system makes more complex, but modern electronic controllers can operate these system automatically. Installation of many distributed generations (DGs) could be detrimental to the power quality of utility grids. Microgrids facilitate effortless installation of DGs in conventional power systems[24]. Amplitude death is a coupling induced stabilization of the fixed point of a dynamical system. This paper applies amplitude death methods to the stabilization problem in this constant-power setting[25].

This model is used in simulation studies to validate system design such as the maximum power point tracking algorithm and micro grid system. It is often difficult to simulate a PV module characteristic under different environmental conditions due to the limited information provided by the manufacturers. A new approach using particle swarm optimization (PSO) with inverse barrier constraint is proposed to determine the unknown PV model parameters[14]. Non linear algebraic constraints, which are introduced by PV array, battery as DAEs and modelica language is employed to describe system as an acausal model organised as separate modelica classes for different components. It gives thoroughly indicating accurate prediction of all system behaviour including mode transitions[15].

The objective of Nonlinear predictive control analysis used to
1.Regulate voltage level, proportional power sharing, and battery management,
2.IU regime to increase life span of battery.
3.The variable load demands are also shared accurately between generators.
This paper is organized as follows: Section II block diagram and description. Section III shows the system modelling and design. Section IV presents and discusses the obtained results. Finally, the conclusion of the study is given in Section V.

II.BLOCK DIAGRAM AND DESCRIPTION

The variable speed operation is more flexible for the power management and MPPT applications. hybrid with solar and wind technologies for generation and lead acid batteries used for storage purposes. Initially solar array consists of PV panels are generally rated according to the maximum DC power output. Furthermore, direct-drive coupling is more efficient and reliable and is more popular for small-scale wind turbines.

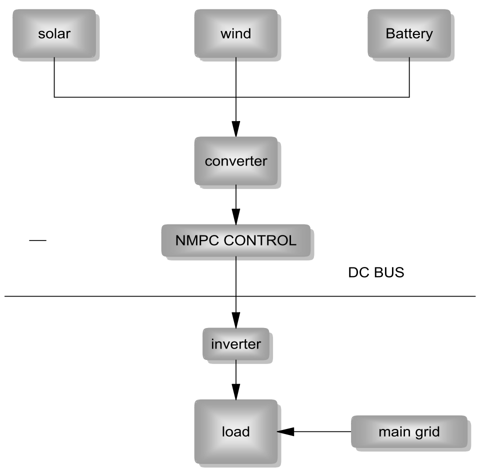

Fig. 1. Block diagram of proposed system

In spite of high cost, permanent magnet synchronous generators (PMSGs) are the most dominant type of direct-drive generators in the market, chiefly due to higher efficiency. It dealts that an excess power greater than or equal to the maximum possible absorbing rate of the battery bank, the hybrid nature of the battery bank operation is ignored for the sake of simplicity.

In contrast to the strategies available in literature in which renewable energy systems (RESs) always operate in their MPPT mode, the proposed multivariable strategy uses a wind turbine and a PV array as controllable generators and curtails their generations if it is necessary. The proposed EMS is developed as an online novel NMPC strategy that continuously solves an optimal control problem (OCP) and finds the optimum values of the pitch angle and three switching duty cycles. It simultaneously controls four variables of microgrids are power coefficient of the wind turbine, angular velocity of the wind generator, operating voltage of the PV array and charging current of the battery bank.

III. SYSTEM MODELLING AND DESIGN

NMPC is an inherently non-linear and multivariable strategy that handles constraints and delays. Recently, NMPC became an attractive approach for the control of constrained non-linear processes because of better understanding. Although one can show the well posedness and stability of the involved OCP1 when the infinite horizon optimal control sequence, u_(:), exists at the time instance t = 0, it is not practical, either analytically or numerically, to solve OCP1. In order to be able to numerically solve a non-linear open-loop optimal control problem, it must be formulated as a finite horizon approximation. However, such a finite prediction horizon T, even when there is no disturbances, causes two major issues: First, the shorter finite horizon, the more deviation there would be between the optimal open-loop solution of the finite horizon prediction and real closed-loop trajectories. It is shown that they converge together if the finite horizon approximation problem is solved consecutively with the same cost function over a receding optimization horizon.
Second, there is no guarantee that the optimal solution of the finite horizon approximation stabilizes a closed-loop system. In order to make the resulting closed loop system stable, the stage cost requires being modified by adding a penalty terms to it, as given in (1.13a), and adding equality or inequality constraints on feasible states, as in (1.13b):

$$J_T(x,z,u;t) := \int_t^{t+T} \mathcal{L}(x(\tau),z(\tau),u(\tau))d\tau + \mathcal{M}(x(t+T),z(t+T)), \qquad (1.13a)$$

$$x(t+T) \in \Omega \subseteq \mathcal{X}. \qquad (1.13b)$$

While the terminal penalty term M indicates the cost of state deviations from the desired final values, the term shows terminal region constraint. Both freely chosen M and are determined suitably in an off-line manner in order to guarantee the stability of the closed-loop system. They can be such that the new cost function in gives an upper approximation of the original infinite horizon cost functional. In order to find the upper approximation of the infinite horizon cost functional, it can be split into two segments: Although it is not possible to find an upper approximation for general non-linear systems, if there is a terminal region around origin within which trajectories of the closed-loop system remain for a time interval of [t + T;1], then it is possible to find an upper bound on the second term

$$\underset{u(.)\in\mathcal{U}^{\infty}}{\text{minimize}} \; J_{\infty}(x,z,u;t,x_0) =$$

$$\underset{u(.)\in\mathcal{U}^{\infty}}{\text{minimize}} \left(\int_t^{t+T} \mathcal{L}(x(\tau),z(\tau),u(\tau))d\tau + \int_{t+T}^{\infty} \mathcal{L}(x(\tau),z(\tau),u(\tau))d\tau \right). \qquad (1.14)$$

This upper approximation of the second term can be used as the terminal penalty given by term M. It is important to note that though adding terminal penalty cost is very effective to obtain stability and feasibility of NMPC problems, it is not a necessary condition. There are new advances to stabilize NMPC problems without adding terminal constraints to the original problem.

NMPC, also known as non-linear receding horizon control (RHC), repeatedly solves on-line a finite horizon version of an OCP in order to obtain the optimum control signals at each sampling instant. NMPCs are digital control strategies which are based on discrete finite-horizon OCPs. It shows the finite horizon discrete version of the OCP given. The period of time T in (1.13) is divided into N equal or non-equal length samples with the duration of h = TN in which the control variables are assumed to be constant optimizer, a cost function, as well as a number of constraints. It also relies on, as part of the relevant OCP, a model of the plant to predict its behaviour. The current values of the plant internal states, ^x, need to be measured or estimated at k and applied to NMPC as their initial values. It explains that, at any sampling instant k, controller calculates the optimum input trajectory u_(:) for a finite prediction horizon T = N _h where h is the sampling length.

A.photo voltaic system

PVs are among the popular renewable energy components to harvest solar energy. A PV cell, as the fundamental PV element, is a P-N junction that converts solar irradiance to the electrical energy. Normally, manufacturers provide PV modules, also known as PV panels, which consist of several PV cells connected together in series.

The equivalent electrical circuit of the PV module is used to mathematically model the solar branch, consisting of a PV array and a boost converter. It shows the characteristic equations of a PV array, consisting of PV modules.

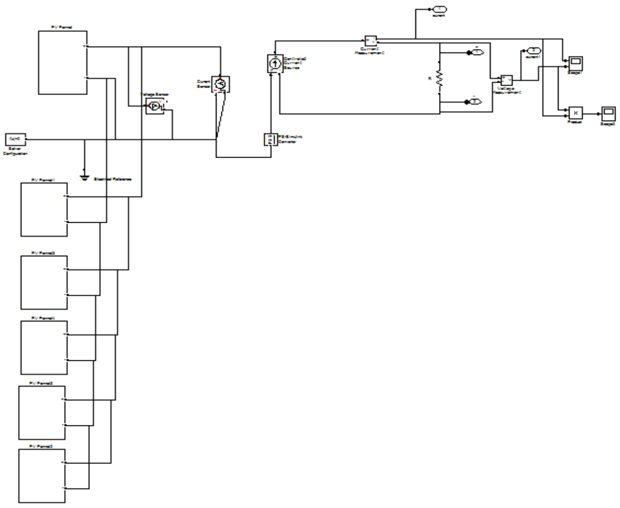

Fig. 2. Simulation diagram of PV module

B. Wind System

Wind turbines (WTs) convert the kinetic energy of wind to mechanical power. The performance of a WT can be characterized with three different curves, namely power, torque, and thrust coefficient curves. These curves are normally plotted in terms of tip speed ratio, which is defined as a weighted ratio of the rotational speed to wind speed, for different values of pitch angle. The optimum value of tip speed ratio at which the power coefficient, Cp, is maximized. According to the Lanchaster-Betz theory, the upper bound of power coefficient, i.e. Cp; max, is 0:593. Modern wind turbines provide the maximum power coefficient of around 0.48. Regarding the rotational speed, a WT operation can be classified into either constant speed or variable speed. The variable speed WT operation, which requires employing power converters, is more attractive, principally due to its ability to harvest the maximum power at variable wind speeds. In order to generate the maximum power by a WT at variable wind speed, it is necessary to employ a maximum power point tracking (MPPT) control strategy.

A wind turbine can be connected to an electrical generator directly or through a gear-box. The former case, which is called direct-drive, provides some advantages in terms of high reliability and is more popular for small-scale wind turbines. To deliver power in direct-drive topology, which operates at low rotational speed, it requires employing multi-pole generators. In spite of high cost, PMSGs are the most dominant type of direct-drive generators in the market, due to several advantages such as higher efficiency.

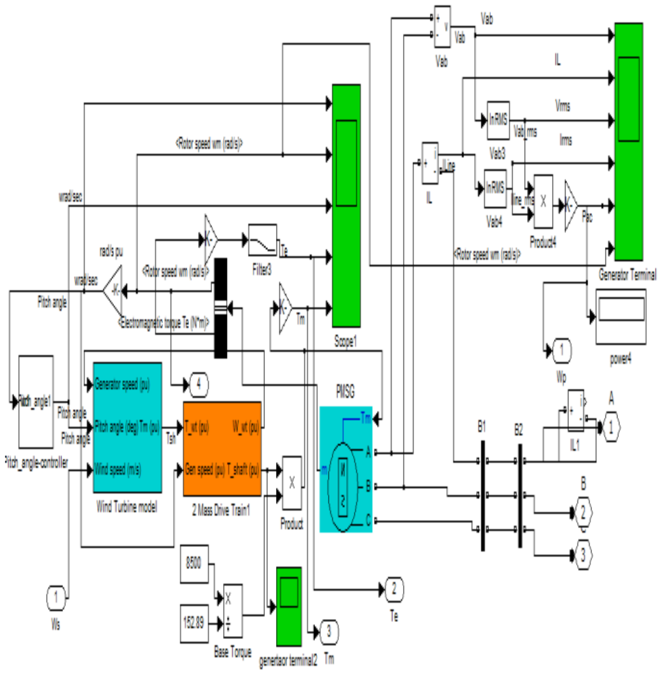

Fig. 3. Simulation diagram showing wind mill

C. Battery System

The diagram explains lower voltage than the input voltage. Unlike the boost and buck converters which dictate the instantaneous current flow to be unidirectional. It shows a bi-directional converter. In such a converter a complementary control signal allows the current to flow in either direction. A state-space averaging approach to model a dc-dc converter is proposed. It suggests two states, Il and Vc for the continuous conduction mode (CCM) in which the instantaneous inductor current, Il, is always greater than zero. According to the proposed approach, there is a set of two distinct state-space systems to model two states of switch operation and the overall state-space model of the converter is a weighted average of these two models.

The weighting factor is the duration of time that converter remains in each state. While state-space averaging approach is simple to analyse and implement, it does not model the hybrid nature of converters. One-level dc-dc converters work in two different modes of operation with respect to the value of discrete state Sd. Defining the same state vector as above, i.e. XT = [Il Vc]T , dc-dc converters can be modelled as hybrid systems. It presents an affine state space model coupled with a linear output equation for each modes of operation.

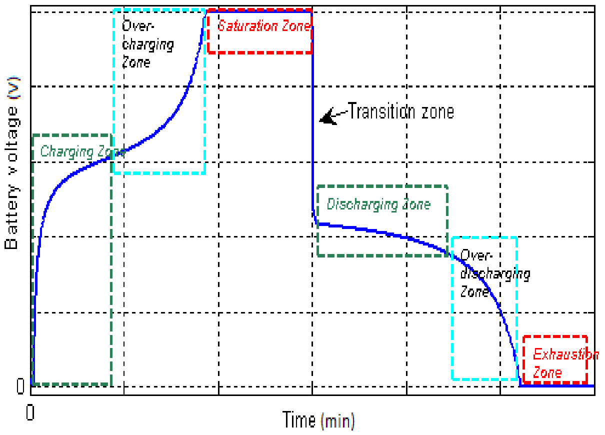

Fig. 4. charging and discharging mode of battery

Batteries are one of the most uneconomic components in both microgrids and EVs, principally due to their high cost of replacement which is highly dependent on the charging and discharging methods. Therefore, it is essential to implement a proper battery management strategy as part of any EMS. The researches in have introduced implementations of different battery management strategies as standalone systems. Moreover, the works in have provided battery management strategies as a part of the developed EMSs. A number of prior works presented different control techniques to implement EMSs.

IV.RESULTS AND DISCUSSION

The output power of solar, angular velocity and additional parameters of power coefficient, pitch angle in wind system, current and voltage level output in battery management, track point in nmpc to be analysed. Each output to be analysed with time scale.The predicted value will be noticed as compared with the nmpc designed value for the future purpose. It is able to get nmpc value as predicted so that value could be generated equal to the output value. The system manages to either increase or decrease generated input to the load demand. The graph explains that different wavelength of irradiance in pv array gives variable output power. Converter used to regulate power flow in a circuit. Pv array connects to DC link before the value will be corrected.

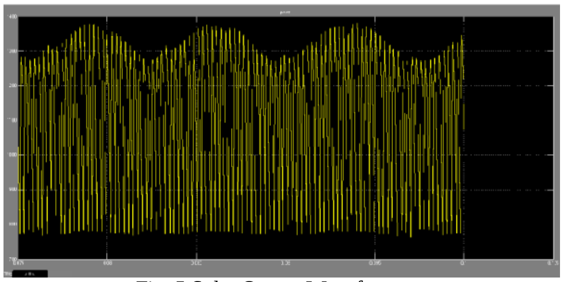

Fig. 5.Solar Output Waveform

The graph explains performance of the wind turbines is measured as the power coefficient curve with respect to the tip speed ratio and pitch angle. Energy management strategies of microgrids must estimate the dc bus voltage level deviation from its set point in about every 5–10 s. It means that except the angular velocity of the generator, all other fast voltage and current dynamics can be ignored. It is also assumed that there is no mechanical and electrical losses through the network and therefore the electromagnetic power given is equal to the output electrical power of the wind branch.

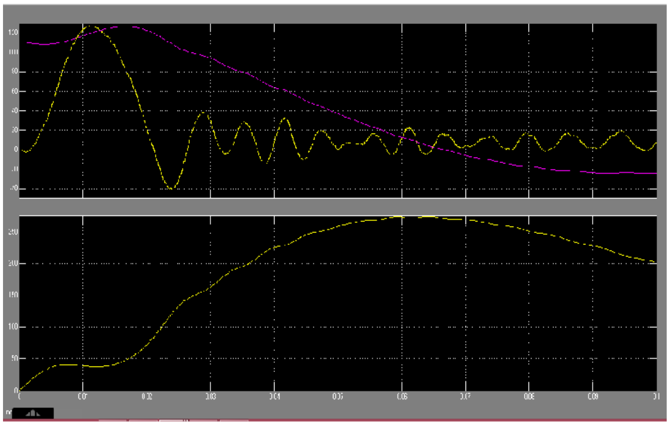

Fig.6. Output Waveform for wind System

Energy management strategies of microgrids must estimate the dc bus voltage level deviation from its set point in about every 5–10 s. It means that except the angular velocity of the generator all other fast voltage and current dynamics can be ignored.

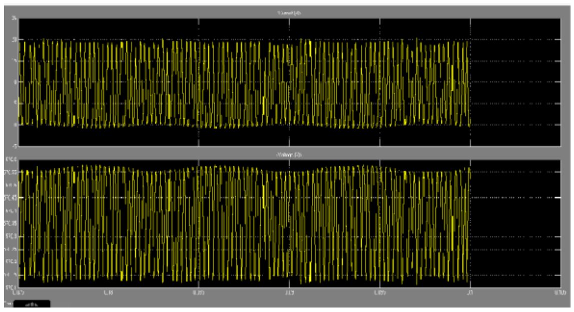

Fig.7. Output Waveform for Battery System

Track point used for proper selection of source to operate value from wind, solar and battery system.

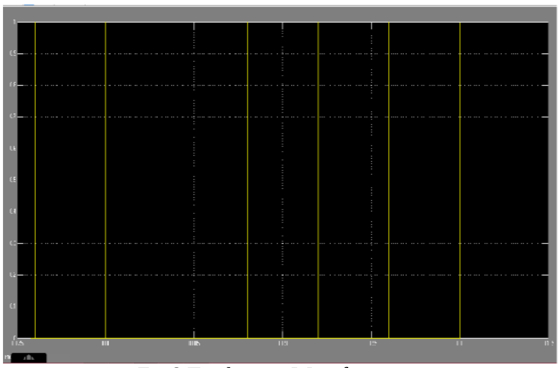

Fig.8.Track point Waveform

It explains design parameters and computational times of the developed NMPC controller. The computational times are calculated on an Intel CORE 2 DOU machine with 3 GB of RAM. It indicate that the microgrid voltage level deviation from the set point is evaluated every 5 s that complies with the hierarchical architecture specifications. The bus voltage level of the microgrid is set externally and hence the developed controller can act as the secondary and primary levels of the hierarchical architecture. The below diagram explains values from solar, wind, battery in y axis and time in x axis.

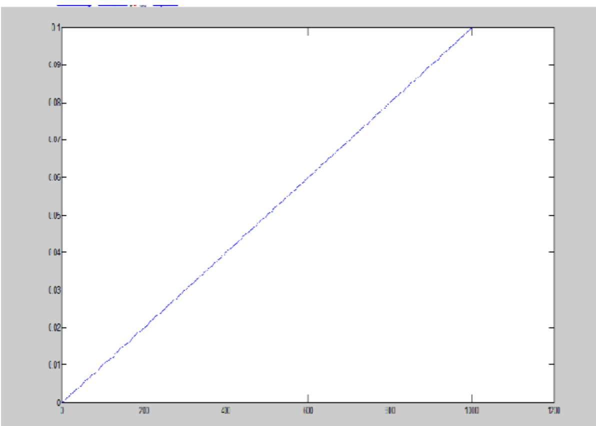

Fig.9 NMPC output Waveform

V.CONCLUSION

The near future distribution networks will consist of several interconnected microgrids that will locally generate, consume, and store energy. ac systems suffer from the need of synchronization of several generators, dc microgrids are more efficient due to the fact that dc generators and storages do not need ac-dc converters for being connected to dc microgrids . The three well-known issues regarding voltage regulation, power sharing, and battery management, are more severe in standalone green microgrids, that consist of only intermittent solar and wind energy sources, and lead to the necessity of more sophisticated control strategies. More deviation there would be between the optimal open-loop solution of the finite horizon prediction and real closed-loop trajectories. The finite horizon approximation problem is solved consecutively converge with the same cost function over a receding optimization horizon. Non-linear receding horizon control (RHC), repeatedly solves on-line a finite horizon version of an OCP in order to obtain the optimum control signals at each sampling instant. Optimal control techniques have become popular recently to solve energy management problems, mainly due to handling constraints and the recent advances in relevant numerical solvers. Three mentioned control objectives, dc bus voltage regulation, proportional power sharing, and implementing the IU regime to charge batteries, are formulated by two slack variables and the cost function. The battery terminal voltage reaches the gassing voltage, the charging current should be gradually reduced in order to maintain the voltage below the gassing level and fully charge the battery without the risk of permanent damage.

REFERENCES

[1] J. Rajagopalan, K. Xing, Y. Guo, and F. C. Lee, “Modeling and dynamic analysis of paralleled dc/dc converters with master-slave current sharing control,” in *Proc. IEEE Appl. Power Electron. Conf.*, 1996, pp. 678–684.

[2] C. K. Sao and P. W. Lehn, “Autonomous load sharing of voltage source converters,” *IEEE Trans. Power Del.*, vol. 20, no. 2, pp. 1009–1016, Aug.2005.

[3] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, M. A. M. Prats, J. I. Leon, and N. Moreno-Alfonso,“Power-electronic systems for the grid integration of renewable energy sources: a survey,” *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

[4] H. Li and Z. Chen, (2008) “Overview of different wind generator systems and their comparisons,” IET Renew. Power Gener., vol. 2, no. 2, pp. 123–138.

[5] Ghassan halasa1, Johnson A. asamudu, (2009) Wind-Solar Hybrid Electrical Power Production to Support National Grid: Case Study – Jordan, Energy and Power Engineering.

[6] Y. W. Li and C. N. Kao, “An accurate power control strategy for powerelectronics- interfaced distributed generation units operating in a lowvoltagemultibus microgrid,” *IEEE Trans. Power Electron.*, vol. 24, no. 12,B pp. 2977–2988, Dec. 2009.

[7] L. Xu and D. Chen, “Control and operation of a DC microgrid with variable generation and energy storage,” *IEEE Trans. Power Del.*, vol. 26, no. 4, pp. 2513–2522, Oct. 2011.

[8] H.-H. Huang, C.-Y. Hsieh, J.-Y. Liao, and K.-H. Chen, (2011)“Adaptive droop resistance technique for adaptive voltage positioning in boost DC–DC converters,” IEEE Trans. Power Electron., vol. 26, no. 7, pp. 1920–1932.